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VI.

Observations on the Comparative Rates of Marine Chronometers.

BY W. CRANCH BOND.

THE following series of observations was arranged, in consequence of an opinion being expressed by some navigators, that Chronometers, when removed from the shore to the ship, have an accelerated rate of going. This was attempted to be accounted for, on the supposition that the influence of iron would tend to produce such an effect. A paper on this subject by George Fisher Esq., read before the Royal Society, June 8, 1820, contained an account of some very extraordinary discrepancies; and if such were common, they would render these instruments of little or no value, as a means of determining the longitude. But, upon examination of the rates of the several Chronometers as therein given, it appears, that the rates of these particular instruments were, even on shore, so unsteady as to make it probable that they were not in such a state as to be worthy of much confidence. For example, the Chronometer by Baird, from the 8th to the 12th of August, was losing 3".4 daily when on board; but on its removal to the observatory on shore, its rate of losing was observed to be 18".2. Upon again removing it on board, it was found to be losing 6".5 daily. Here we see a difference of 3".1 in the *ship-board* rates. Another Chronometer, made

by Arnold, lost about 9" by removal from the vessel to the shore, and another by Pennington still more. The *variation* in the *shore* rates is also remarkable, that of the first appearing to have been 8", of the second 6".14, of the third 7".2, and of the fourth 8". All these errors were noted during the short period of seventeen days.

It is evident, that either the instruments used in these experiments were not well adjusted, or that some extraordinary cause operated to produce the effect described. Mr. Fisher was of opinion that this acceleration arose entirely from the magnetic action exerted by the iron in the ship on the inner rim of the balance of the Chronometer, which is made of steel; that the iron in the ship forms "altogether one large magnet, having its south pole, on deck, nearly amidships, and its north pole below;" and all his subsequent experiments were made on the supposition that the magnetism was fixed. It is, however, well known, that a bar of iron, in the state in which it commonly occurs, will affect the magnetic needle very differently when placed in different positions as it regards the magnetic equator. Hence if the balance is to be considered as a nicely suspended magnet, it would follow that every different inclination of the vessel would produce a corresponding change of rate.

It is better in the first place to ascertain from direct experiment whether Chronometers have or have not any systematic variation, dependent on their being placed on ship-board. The tables of the change of rates of Chronometers furnished by Mr. George Coleman, which accompany Mr. Fisher's communication, go a great way toward reducing the excessive errors which were thought to exist; but these are generally defective in not giving the subsequent shore rates, as there are many

excellent Chronometers, that have a tendency gradually to gain or lose in their rates, particularly new instruments; and the mean rate, corrected for this acceleration or retardation, as it shall have been ascertained by actual observation on shore, may usually be relied upon with great confidence for several months. Without using this precaution we might fall into dangerous errors.

The subjoined Table contains two hundred and twenty-six cases, and embraces almost every possible variety in regard to the size of the vessel, the cargo, the duration of the voyage, the change of temperature, and the different makers. The first or the last shore rate was determined by myself in every instance, and generally both. No particular selection has been made in regard to the Chronometers used; those only being rejected which were notoriously imperfect. In arranging the Table, the *mean* of the previous and subsequent *shore* rates was compared with the rate on ship-board, and the comparative gain or loss is placed in the column marked, "Excess of gain or loss on ship-board"; except in those instances where the one or the other shore rate was not obtained, in which case the first difference is carried out. A summary is appended to the Table. From an inspection of this Table, the inference appears irresistible, that Chronometers do not gain in their rates in consequence of being removed to the vessel; and if there is an error arising from such removal, which I would not be thought utterly to deny, it is so minute, as to be within the limits of error to which Chronometers, in their present state, are liable on shore, and is such as will require nice and careful observation to detect it.

Makers' names and numbers.	No.	Year.	Previous shore rate + or -	Rate on ship-board + or -	Subsequent shore rate + or -	Excess of gain or loss on ship-board.	Number of days on ship-board.	General remarks.
Charles Young,	10	1825	3.3	4.	3.5	0.6	40	Assorted cargo.
" "	"	"	3.3	3.5	3.5	0.1	30	" "
" "	"	1827	3.5	3.5	3.4	0.0	272	" "
Parkinson & Frodsham,	875	1826	8.4	8.3	7.3	0.4	96	" "
" "	762	"	"	4.5	3.5	1.	53	" "
" "	873	"	"	- 0.5	- 0.3	- 0.2	96	" "
" "	928	"	- 1.	- 0.6	- 0.1	0.0	56	" "
" "	427	1825	- 1.7	- 3.9	- 2.5	- 1.8	156	" "
" "	"	1826	- 2.5	- 3.0	- 2.2	- 0.6	167	" "
" "	920	1826	8.4	8.1	7.1	0.2	153	" "
" "	"	1827	7.1	9.1	8.1	1.5	40	" "
" "	966	1827	0.6	2.0	4.	- 0.3	46	" "
" "	873	"	- 0.3	0.1	- 1.1	0.8	53	" "
Barraud,	457	"	- 2.5	- 2.4	2.0	- 2.2	55	" "
J. M. French,	1990	"	- 1.0	- 0.7	2.8	- 1.6	55	" "
Parkinson & Frodsham,	981	"	- 0.6	- 0.2	- 0.7	0.4	55	" "
Richard Hornby,	119	1826	- 4.0	- 5.9	- 4.0	- 1.9	229	" "
John Wood,	155	1827	- 3.4	- 6.5	- 7.7	- 1.0	200	40 tons of iron.
Penlington,	2918	"	4.6	2.8	3.8	- 1.4	64	Assorted cargo.
Parkinson & Frodsham,	1030	"	- 0.4	0.2	2.3	- 0.7	64	" "
" "	920	"	8.1	8.8	8.2	0.7	157	" "
" "	534	"	- 0.4	- 1.6	- 2.7	- 0.1	63	" "
Robert Roskell	229	"	2.5	0.4	2.4	- 2.0	44	" "
Parkinson & Frodsham,	811	"	- 1.1	- 1.1	0.1	- 0.6	34	" "
John Wood,	70	"	3.	- 3.9	- 2.3	- 4.2	51	" "
" "	3148	"	- 8.5	- 8.5	- 7.0	- 0.8	"	" "
Parkinson & Frodsham,	871	"	- 5.9	- 6.5	- 7.5	0.2	186	" "
" "	919	"	5.5	5.5	6.5	- 0.5	"	" "
" "	684	"	5.4	5.7	"	0.3	"	" "
" "	889	"	5.7	7.0	8.1	0.1	"	" "
J. Moncas,	2896	"	2.5	3.1	3.5	0.1	36	" "
Parkinson & Frodsham,	1056	"	1.5	3.2	5.7	- 0.4	52	" "
J. Moncas,	5564	"	4.5	9.7	13.5	0.7	98	" "
Parkinson & Frodsham,	698	1826	4.3	3.2	4.2	- 1.0	41	" "
Robert Roskell,	168	1827	"	5.0	4.6	0.4	89	" "
John Wood,	553	"	- 12.5	- 13.1	- 9.5	- 2.1	177	" "
Hatton & Harris,	498	"	- 22.5	- 26.9	- 29.3	- 1.0	170	" "
Parkinson & Frodsham,	669	1826	- 3.6	- 3.6	- 2.7	- 0.5	294	" "
Finer & Nowland,	"	1827	3.3	3.1	0.7	1.1	37	" "
Parkinson & Frodsham,	704	"	3.8	4.3	4.2	0.3	62	" "
" "	832	"	10.8	11.9	11.5	0.7	59	" "
" "	873	"	- 0.4	- 1.8	- 0.7	- 1.3	50	" "
" "	1091	"	- 1.0	0.1	- 0.1	0.6	50	" "
" "	1079	"	- 0.9	1.3	5.2	- 0.8	50	" "
" "	594	"	- 2.8	- 2.2	0.4	- 1.0	36	" "
Hedge & Bannister,	6844	1824	- 3.0	- 6.5	- 5.7	- 2.2	75	" "
Parkinson & Frodsham,	891	1827	1.0	1.0	1.7	- 0.3	161	Sugar, &c.
" "	"	"	"	1.7	- 1.7	3.4	32	150 tons of iron.
" "	933	"	4.0	10.	10.6	2.7	53	Assorted cargo.
" "	866	"	5.5	7.2	7.0	1.0	60	" "
" "	928	1826	0.1	0.8	"	0.7	65	" "
" "	"	1827	0.1	1.7	4.8	- 0.7	90	Sugar, &c.
" "	"	"	"	2.4	4.8	- 2.4	"	30 tons of iron.
John Wood,	550	1826	1.6	3.2	"	1.6	173	Assorted cargo.
" "	"	1827	- 3.2	- 4.7	- 4.1	- 1.1	60	" "
John Moncas,	2575	"	3.0	5.0	6.4	0.3	43	" "
Parkinson & Frodsham,	887	"	18.2	19.5	18.5	1.2	56	" "
John Wood,	146	"	5.0	5.	2.5	1.2	20	Salt, grindstones.
" "	"	"	5.0	3.8	2.5	0.0	133	Sugar and coffee.
" "	"	"	5.0	2.2	2.5	- 1.5	107	350 tons of iron.
John Penlington,	2918	"	2.0	1.3	- 2.1	1.3	31	Transport.
Parkinson & Frodsham,	752	"	2.8	3.7	3.2	0.7	59	30 tons of iron.
Widenham,	941	"	7.3	9.8	7.3	2.5	49	Fruit.

Makers' names and numbers.	No.	Year.	Previous shore rate + or -	Rate on ship-board + or -	Subsequent shore rate + or -	Excess of gain or loss on ship-board.	Number of days on ship-board.	General remarks.
Widenham,	941	1827	7.3	10.1	9.2	1.9	51	Fruit.
Parkinson & Frodsham,	549	1826	- 2.4	- 1.5	- 0.5	- 0.1	388	"
J. M. French,	367	"	8.0	8.		0.		"
J. R. Arnold,	1678	1827	- 1.5	- 8.2	-10.8	- 2.1	72	Corn.
Roskell,	168	"	5.0	5.1		0.1	76	Assorted cargo.
Parkinson & Frodsham,	871	"	- 7.5	- 8.6	-11.3	0.8	72	"
Brockbank,	711	"	- 4.0	- 5.2	- 1.4	- 2.5	119	"
Thompson,	661	"	3.0	- 5.3	- 3.0	- 5.3	94	"
John Wood,	148	"	- 0.8	0.9		1.7		"
Parkinson & Frodsham,	1035	"	0.	0.7	0.5	0.2	116	"
"	920	"	8.1	8.4	7.0	0.9		"
"	"	"	7.0	8.8	7.8	1.4	54	"
Arnold,	388	"	- 2.0	- 6.1	- 8.4	- 0.9	79	"
Parkinson & Frodsham,	799	"	"	8.7	8.3	0.4	101	Sugar, coffee, &c.
"	"	"	"	5.6	8.3	0.3	50	300 tons of iron.
John Wood,	30	1821	0.8	- 3.0	- 3.0	- 1.9	232	Assorted cargo.
"	31	1824	- 2.2	- 2.5	- 2.2	- 0.3	88	"
"	"	1825	- 2.2	- 2.8	- 3.1	- 0.2	484	"
Parkinson & Frodsham,	905	1826	- 1.8	- 2.6	- 2.2	- 0.6	54	"
John Gibson,	"	"	- 6.9	- 8.1	- 5.	- 2.2	72	"
Parkinson & Frodsham,	887	"	2.7	9.5	12.2	2.1	63	"
Duncan,	53	"	- 3.7	- 2.6	- 4.1	1.3		To China and
John Wood,	1315	"	5.4	4.4	4.0	- 0.3	55	home.
Parkinson & Frodsham,	835	1827	5.7	9.2	7.5	2.6	165	Assorted cargo.
"	871	1826	- 4.1	- 6.4	- 5.9	- 1.4	120	"
"	"	1827	- 5.9	- 7.1	- 7.5	- 0.4	200	"
"	1061	"	- 1.6	- 2.2	- 0.8	- 1.0	61	"
Ham,	373	"	- 4.5	- 5.3	- 5.8	- 0.2	210	"
John Wood,	151	"	9.5	7.4	- 0.1	2.6	144	"
Parkinson & Frodsham,	1090	"	1.0	0.2	- 0.8	0.1	109	"
J. M. French,	366	"	-14.5	-15.5	-16.1	- 0.2	79	"
Parkinson & Frodsham,	901	"		20.5	19.0	1.5		India.
"	919	1826	- 0.2	- 0.9	- 1.9	0.1	47	"
G. Hornby & Son,	85	1822	5.0	5.0	5.5	- 0.2	35	"
Robert Roskell,	140	1823	1.0	- 1.6	- 4.3	0.0	241	"
Hatton & Harris,	591	"	- 2.4	- 2.7	- 4.0	0.5	203	"
S. J. Tobias,	3359	1825	2.5	0.1	- 0.2	- 1.0	112	"
Parkinson & Frodsham,	234	1824	- 1.3	- 3.2	- 0.3	- 2.4	387	India and home.
Robert Roskell,	307	1826	-13.7	-14.4		- 0.7	100	"
Parkinson & Frodsham,	427	1824	2.1	0.3		- 1.8	37	"
J. M. French,	3837	"	2.5	- 5.7	2.0	- 7.9	49	Assorted cargo.
Duncan,	641	"	- 3.5	- 2.6	- 6.1	2.2	49	"
John Wood,	146	"	- 2.5	1.3	3.7	0.7	54	"
Parkinson & Frodsham,	981	1827	- 0.6	1.8	3.6	0.3	113	"
"	125	1825	- 7.6	- 8.0	- 8.0	- 0.2		Pacific ocean.
"	"	1826	- 8.0	- 7.5	- 6.9	0.0		"
John Wood,	156	1827	- 0.5	- 1.1	- 3.7	1.0	67	"
J. Johnson,	36	1825		- 4.4	- 3.9	- 0.5		China.
Parkinson & Frodsham,	727	1827	8.0	6.3	8.0	- 1.7	169	Assorted cargo.
"	"	1828	8.0	6.6	4.4	0.4	28	"
"	1030	1827	3.0	1.9	2.2	- 0.7	57	"
"	549	1826	- 4.2	- 3.9	- 2.4	- 0.6	169	"
"	669	1824	- 0.8	0.1	0.5	0.2	45	"
"	"	"	1.0	- 4.9	- 5.6	- 2.6	107	"
"	"	1825	- 5.6	- 5.5	- 4.1	- 0.7	187	"
"	"	"	- 4.1	- 4.1	- 3.6	- 0.3	338	"
"	"	1826	- 3.6	- 3.6	- 2.7	- 0.5	294	"
"	"	1827	- 2.7	- 3.6	- 2.5	- 1.0	143	"
"	1052	"	1.0	5.9	5.2	2.8	197	"
"	1138	"	1.6	0.6		- 1.0	66	"
John Wood,	3148	1828	- 8.0	- 9.0	- 9.0	- 0.5	33	"
Duncan,	641	1827	2.0	3.0	2.0	1.0	103	"
Parkinson & Frodsham,	811	"	0.2	0.2	- 0.9	0.5	136	"

Makers' names and numbers.	No.	Year.	Previous shore rate + or -	Rate on ship-board + or -	Subse- quent shore rate + or -	Excess of gain or loss on ship-board.	Number of days on ship- board.	General remarks.
J. Johnson,	46	1828	1.0	- 2.0	- 2.0	- 1.5	35	Assorted cargo.
Robert Roskell,	168	1827	10.0	7.5	11.0	- 3.0	75	" "
Parkinson & Frodsham,	534	1828	- 3.7	- 4.8	- 4.7	- 0.6	26	" "
" "	1144	"	- 0.7	0.9	1.6	0.5	44	" "
" "	1100	"	0.6	0.9	0.3	0.5	48	" "
John Wood,	163	1827	- 4.8	- 4.6	- 5.0	0.3	113	" "
Widenham,	955	"	3.2	3.6	3.9	0.1	206	" "
" "	"	1828	3.9	4.8	4.9	0.4	122	" "
Parkinson & Frodsham,	871	"	-11.4	-10.3	-11.8	1.3	69	" "
" "	832	"	11.0	10.8	10.0	0.3	66	" "
J. Johnson,	57	"	4.5	3.9	5.7	- 1.2	252	" "
Thompson,	661	"	- 3.0	- 4.2	- 0.	- 2.7	98	" "
Parkinson & Frodsham,	1047	1827	8.1	9.5	11.5	- 0.3	231	" "
Richard Hornby,	266	"	1.0	1.4	2.0	- 0.1	85	" "
" "	"	"	2.0	5.1	6.1	1.1	105	" "
Parkinson & Frodsham,	1142	1828	- 0.2	0.3	0.1	0.3	58	" "
Moncas,	2575	"	8.5	7.7	9.0	- 1.0	42	" "
John Wood,	30	1827	- 6.8	- 5.2	- 3.5	- 0.1	179	" "
Parkinson & Frodsham,	1184	1828	- 1.0	0.4	2.0	- 0.1	29	" "
" "	430	1821	1.4	5.5	6.5	1.5	240	Homeward cargo, 150 tons of iron.
" "	"	1822	6.5	7.2	10.8	- 1.4	281	" "
" "	1007	1828	- 1.2	- 3.3	- 3.3	- 1.1	32	" "
" "	981	"	4.2	2.7	2.3	- 0.5	95	" "
James Murray	577	"	5.3	2.3	5.3	- 3.	96	300 tons of iron.
Parkinson & Frodsham,	1170	"	2.8	3.0	3.0	0.1	36	" "
" "	1006	"	- 1.5	- 2.9	- 2.2	- 1.0	37	" "
" "	704	"	"	3.6	3.5	0.1	72	" "
Duncan,	53	1827	- 3.2	- 3.5	- 6.8	1.5	"	India.
Parkinson & Frodsham,	613	"	- 7.0	- 7.9	- 7.9	- 0.5	176	" "
" "	430	1825	11.0	11.2	15.5	- 2.0	137	Homeward cargo, 150 tons of iron.
" "	"	1826	15.5	15.5	13.1	1.2	175	Fruit.
" "	"	"	13.1	15.	17.2	- 0.1	142	Homeward cargo, 150 tons of iron.
" "	"	1827	- 2.5	- 1.4	- 1.0	0.3	313	Assorted cargo.
John Wood,	151	1828	5.5	6.5	5.7	0.9	30	" "
Robert Roskell,	268	"	- 1.0	- 4.0	- 7.4	0.2	317	" "
Parkinson & Frodsham,	811	"	- 0.9	0.2	"	0.2	86	" "
Duncan,	641	"	2.0	3.7	- 5.2	0.1	91	" "
Parkinson & Frodsham,	871	"	-12.0	- 9.6	- 8.6	0.7	89	" "
" "	439	"	7.0	7.5	10.2	- 1.1	127	" "
" "	866	"	7.1	6.8	7.3	- 0.4	101	" "
" "	698	"	12.2	9.9	12.0	- 2.2	175	" "
John Wood,	155	1827	- 7.5	- 6.5	- 7.1	0.8	"	" "
Parkinson & Frodsham,	832	1828	10.0	14.	17.	0.5	114	" "
" "	1122	"	2.0	2.6	5.0	- 0.9	95	" "
" "	"	"	5.0	7.1	9.3	0.0	53	" "
Arnold,	388	"	- 5.5	- 5.1	- 4.0	- 0.4	154	" "
Parkinson & Frodsham,	609	1827	- 3.5	- 3.3	- 3.6	0.3	220	" "
" "	966	1828	6.2	8.6	11.6	- 0.3	120	" "
" "	1091	"	2.6	4.8	8.2	- 0.6	77	" "
" "	873	"	1.5	1.5	1.5	0.0	27	" "
" "	"	"	1.5	= 0.0	1.6	- 1.5	45	" "
Roskell,	102	"	10.0	14.0	13.3	2.4	136	" "
Parkinson & Frodsham,	1030	"	2.3	3.4	4.1	0.2	177	" "
John Wood,	3148	"	-12.8	-12.3	-12.0	0.1	27	" "
" "	"	"	-12.0	-13.1	-15.6	0.7	56	" "
Parkinson & Frodsham,	1146	"	2.3	2.6	3.8	- 0.4	47	" "
Charles Young,	10	"	3.8	4.2	5.8	- 0.6	408	India.
Parkinson & Frodsham,	933	"	11.5	15.4	25.7	- 3.2	282	" "
John Arnold,	10	"	2.8	6.4	5.4	2.3	241	" "
Parkinson & Frodsham,	1056	"	10.0	12.8	18.6	- 1.5	346	" "

Makers' names and numbers.		Year.	Previous shore rate + or -	Rate on ship-board + or -	Subse- quent shore rate + or -	Excess of gain or loss on ship-board.	Number of days on ship- board.	General remarks.
	No.		"	"	"	"		
Parkinson & Frodsham,	1174	1828	- 4.0	- 9.0	11.0	- 1.5	55	Assorted cargo.
" "	1179	"	- 2.0	0.9	3.7	0.0	55	" "
" "	1100	"	3.0	4.3	5.5	0.0	55	" "
" "	900	"	9.9	14.8	16.9	1.4	56	" "
" "	599	"	6.0	6.2	8.1	- 0.8	56	" "
Barraud,	2-551	"	- 5.5	- 3.0	- 7.4	3.4	192	" "
Parkinson & Frodsham,	508	1826-8	8.5	10.5	12.3	0.1	677	" "
Robert Roskell,	458	1828	2.5	3.3	3.2	0.5	64	" "
Barraud,	413	"	3.5	0.5	3.1	- 2.8	56	" "
Parkinson & Frodsham,	1028	"	1.3	0.4	1.9	- 1.2	41	" "
" "	940	"		2.0	1.9	0.1		" "
" "	669	"	- 2.0	- 3.4		- 1.4	199	" "
" "	981	"	3.5	3.4	3.0	0.2	146	" "
" "	1210	"	- 1.5	0.4	- 2.5	2.4	58	" "
" "	521	"	- 1.2	- 1.1	- 1.6	0.3	74	" "
" "	752	"	3.4	6.4	7.3	1.1	209	" "
" "	947	"	4.7	6.3	10.0	- 1.0	254	" "
Thompson,	661	"	- 2.0	- 6.0	- 1.2	- 4.4	200	" "
Parkinson & Frodsham,	430	"	- 0.5	0.6	- 1.7	1.7	167	" "
" "	832	"	17.0	15.7	16.7	- 1.1	83	" "
" "	599	"	8.1	7.9	7.5	0.1	84	" "
" "	873	"	1.6	0.6	- 0.4	0.0	95	" "
Richard Hornby	309	"	- 2.7	- 4.4	- 5.7	- 0.2	42	" "
Widenham,	934	"	5.3	1.0	- 5.0	0.9	80	" "
Parkinson & Frodsham,	937	"	6.0	4.1	8.5	3.1	57	" "
John Wood,	39	"	- 3.5	- 2.2	- 4.1	1.6	214	" "
Parkinson & Frodsham,	1053	"	- 1.8	- 1.8	- 1.8	0.0	61	" "
" "	1246	"	2.0	4.0	5.4	0.3	61	" "
" "	966	"	- 1.0	- 1.9	- 1.5	- 0.6	112	" "
" "	1184	"	4.1	4.2	3.9	0.2	68	" "
" "	1088	"	4.5	- 2.2	- 0.3	0.2	60	" "
" "	901	"	- 0.2	- 0.7	- 1.2	0.0	50	" "
Brockbank,	412	"	- 3.8	- 7.4	- 11.8	0.4	99	" "
Parkinson & Frodsham,	1210	1829	- 1.7	- 1.5	- 2.0	0.3	47	" "
" "	1242	"	- 1.0	- 2.6	- 2.8	- 0.7	47	" "
" "	635	1828	- 1.5	- 2.3	- 2.4	0.3	102	" "
" "	"	1829	- 2.6	- 5.5	- 5.3	- 1.5	41	" "
" "	1100	"	2.3	2.1	2.3	- 0.2	57	" "
" "	1215	"	- 2.1	0.2	1.1	0.7	57	" "
" "	1030	"	4.1	4.2	4.9	- 0.3	202	70 tons of iron.

SUMMARY.

Whole number of Cases	226
Number in which there appears to have been an <i>acceleration</i> on the mean of the first and last shore rates	105
Number wherein there appears to have been a <i>loss</i> on the mean of the first and subsequent shore rates	108
Difference	3
Number wherein the error did not exceed a second	149
Number wherein the error did not exceed two seconds	194
Number wherein the error did not exceed one tenth of a second	32